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INSTALLATION AND MONITORING OF A TP 2000-30 kW STOKER

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Executive Summary

A TP 2000-30 kW chip-fired stoker was installed and monitored over the 1987-1988 heating season in a 140 square-meter (1,500 square-foot) farm house, near Rockland, Ontario. The stoker was connected to a Hunter Enermax furnace which served as a heat exchanger. It was fuelled with hardwood pulp-mill-quality chips at an average moisture content of 35 per cent (wet base). With the hold-fire mode set at its maximum, system efficiency was 49 per cent, delivering an average of 18.6 MJ/h over the months of January, February and March. Reducing the hold-fire mode to its lowest adjustment would have increased system efficiency to 59 per cent. Operating full time, the system was capable of delivering over 40 MJ/h (11 kW or 38,000 Btu/h) as installed. Adjusted for maximum output in optimum laboratory conditions, this system is capable of three times this peak output.

The installation was practically creosote-free and operated without any major problems.

Résumé

Un alimentateur automatique aux copeaux de bois TP 2000-30kW a été installé dans une maison de ferme de 140 m carrés (1500 pi. carrés), près de Rockland, en Ontario. Son opération fut observée au cours de l'hiver 1987-1988. L'alimentateur automatique était branché sur un générateur d'air chaud Hunter Enermax qui lui servait d'échangeur de chaleur. Des copeaux de bois pour la pâte de papier furent utilisés comme combustible. Leur teneur moyenne en humidité, sur une base humide, était de 35%. Avec le mécanisme de retention de feu ajusté à son maximum, le rendement du système a été mesuré à 48.9%, avec une puissance moyenne de 18.6 MJ/h durant les mois de janvier, février et mars. En ajustant le mécanisme de retention de feu à son minimum, le système aurait possiblement opéré à un rendement de 59%. En opération continue, il aurait été capable d'une puissance de plus de 40 MJ/h (11 kW ou 38,000 Btu/h), tel que configuré. Si l'ajustement de l'alimentateur avait été modifié pour un maximum de puissance, ce système aurait été capable de trois fois ce débit de chaleur.

L'opération s'est avéré sans problème majeur et pratiquement sans production de créosote.

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PREFACE

In September, 1986, IRTA was given a contract by the Renewable Energy Branch of Energy, Mines and Resources to install a Dan Trim particulate fuel burner at the Glaude residence in Rockland, Ontario and to monitor its operation over the 1986/87 heating season. This original contract was entitled "Installation and Monitoring of a Dan Trim Residential Chip Stoker". When the European pre-heater was not delivered by February 1987, the decision was made to install a TP 2000-44kW stoker in André and Rachelle Glaude's home in March of 1987. Its operation was monitored over the remainder of the heating season. The installation and operation of this unit is summarized in a report entitled "Installation and Monitoring of a Residential Wood-Chip Stoker - May 1987". Although the 1987 monitoring period was short, the TP 2000-44kW particulate fuel burner still provided information which was useful in deciding on the requirements for the next winter's heating installation.

The Dan Trim pre-heater was delivered in the spring of 1987. In the fall it was utilized in an emission and safety testing project with numerous other types of particulate fuel burners. When the study revealed several operating problems with the Dan Trim, it was decided to use another appliance to heat the Glaude residence during the winter of 1987/88.

Based on our experience with particulate fuel burners and wood furnaces, we recommended using the smaller TP 2000-30kW stoker connected to a Hunter 801B wood furnace for the 1987/88 heating season.

This report covers the operation and monitoring of this system.

INTRODUCTION

This report describes the installation and monitoring of a TP 2000-30kW stoker at the Glaude residence in Rockland, Ontario over the 1987/88 heating season.

The Glaudes live in a 1500-square-foot bungalow which is approximately 15 years old. The house is heated by a woodstove installed centrally on the first floor and a wood furnace placed in the basement. The stove heats the house in the early fall and late spring. During the remainder of the heating season, the furnace becomes the only source of heat. The Glaude residence has a large amount of air infiltration which makes it difficult to heat on windy days.

The installation site was selected for the following reasons:

- the Glaudes have always burned wood and are experienced woodburners.
- the Glaudes have previous experience with stokers. Their house was heated with an Eshland stoker over two winter (1984/85 and 1985/86) and they operated a TP 2000-44kW stoker during the month of March, 1987.
- the Glaudes own a grain silo which they have used for storing wood chips. They also have several tractors and assorted trailers which they have used for the transport and handling of chips.
- the Glaudes are fish farmers. Their business requires them to pass much of their time at home. This is desirable in that it provides supervision for the installation.
- André Glaude does most types of mechanical and electrical repairs which would be very handy should something malfunction.
- the site is close to several paper mills which use wood chips. This ensures a reliable supply of chips.

The TP 2000-30kW stoker, and the wood furnace which was used as its heat exchanger, were installed by IRTA at the beginning of December 1987 and were in operation by Christmas. The stoker is designed to utilize sawmill chips. In addition, the homeowner has the option of operating the furnace on roundwood should problems develop with the stoker or with the chip supply.

INSTALLATION

A. Appliance description

TP 2000-30kW stoker (ref. Fig. 1)

The TP 2000-30kW stoker is built in Finland. The manufacturer's advertising brochure may be found in Appendix A. The stoker consists of a storage bin, an auger feed mechanism, and a cast steel combustor tube.

The rectangular storage bin has a volume of 0.43 cu.metres (16.5 cu. feet). The bin's cover is gasketed. Lying horizontally in the bottom of the bin there is a large iron wheel with an attached wire whip. The wheel has teeth which are intermeshed with the flights of the auger. When the auger operates, it turns the wheel. The wheel's rotation with whip acts as an agitator and is intended to prevent bridging of fuel in the bin.

The auger is positioned in the bottom of the bin and is driven by 110-volt electrical motor. The auger's rotational speed is controlled by varying the radial distance between an ox-yoke attachment attached to the auger shaft and a ratchet mechanism. The feed rate is determined by the auger's rotational speed.

The 4-inch auger pushes fuel through a 4 - 3/4 inch diameter tube to a cylindrical cast steel combustor tube. A fan supplies combustion air through a series of small holes in the tube, and combustion takes place within this tube.

The stoker's heat output is controlled by a thermostat which regulates both the combustion air fan and the auger feed. When there is no call for heat, the stoker maintains its fire by operating on a "hold-fire" mode. In this mode both the combustion air fan and the auger feed are operated on a periodic basis to keep fuel burning in the combustion chamber. This "hold-fire" sequence may be adjusted to burn from a minimum of 5 seconds every 6 minutes, to a maximum of 30 seconds every 2 minutes.

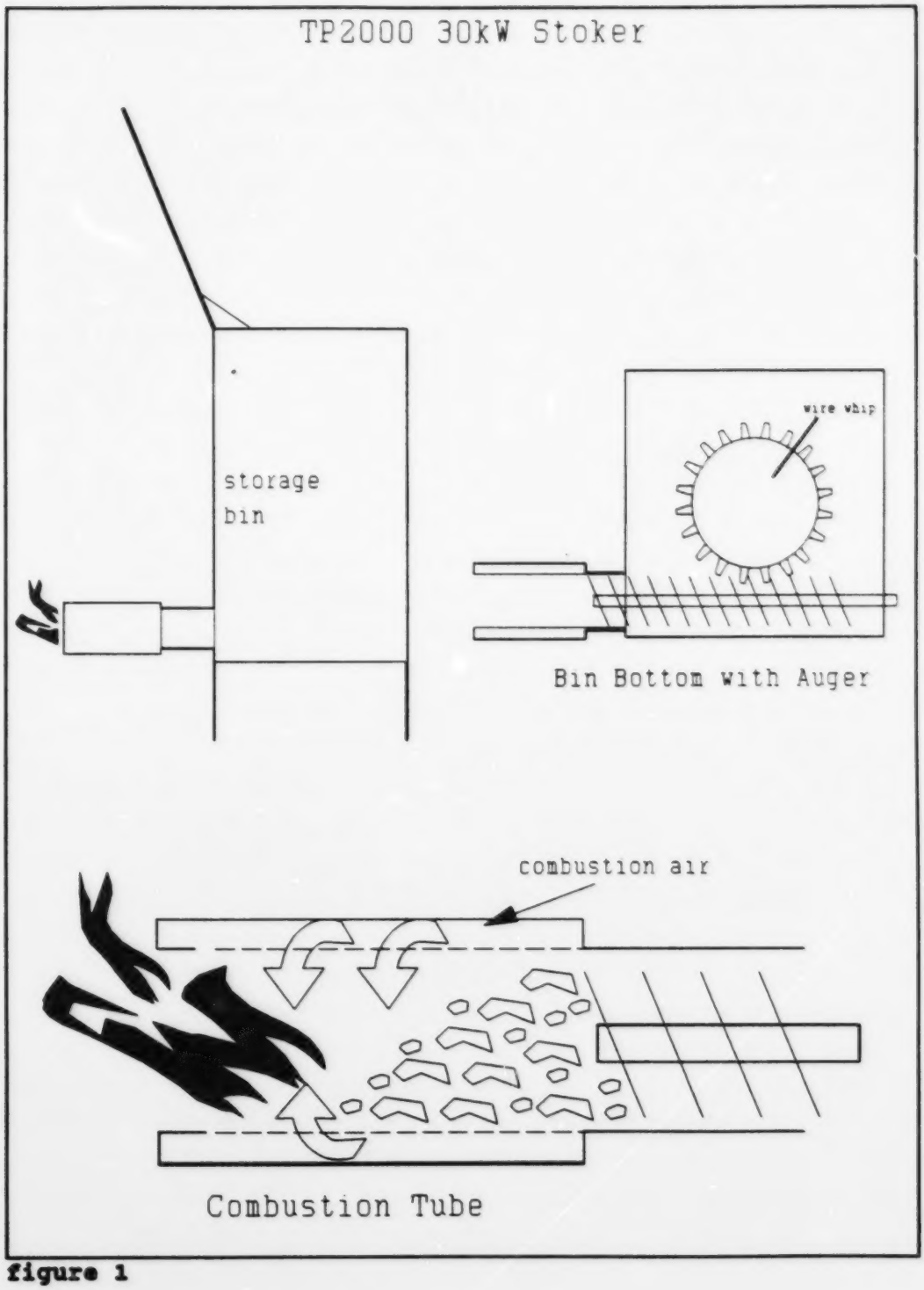
TP2000 30kW Stoker
storage
bin
wire whip
Bin Bottom with Auger
combustion air
Combustion Tube

figure 1

Hunter Enermax 801B wood furnace (ref. Fig. 2)

The Hunter 801B wood furnace was previously tested at IRTA and was chosen for the installation because of its efficient heat exchange characteristics.

The Hunter furnace has a 60 litre (2.1 cu. feet) hexagonal combustion chamber which is manufactured of 8 GA steel. The furnace is not well designed for burning roundwood, mainly because the fire chamber is unlined and it has an oversized heat exchanger. By increasing the insulation on the fire chamber, the furnace was considerably improved for use with roundwood. The large heat exchanger, on the other hand, proved to work very well with the stoker.

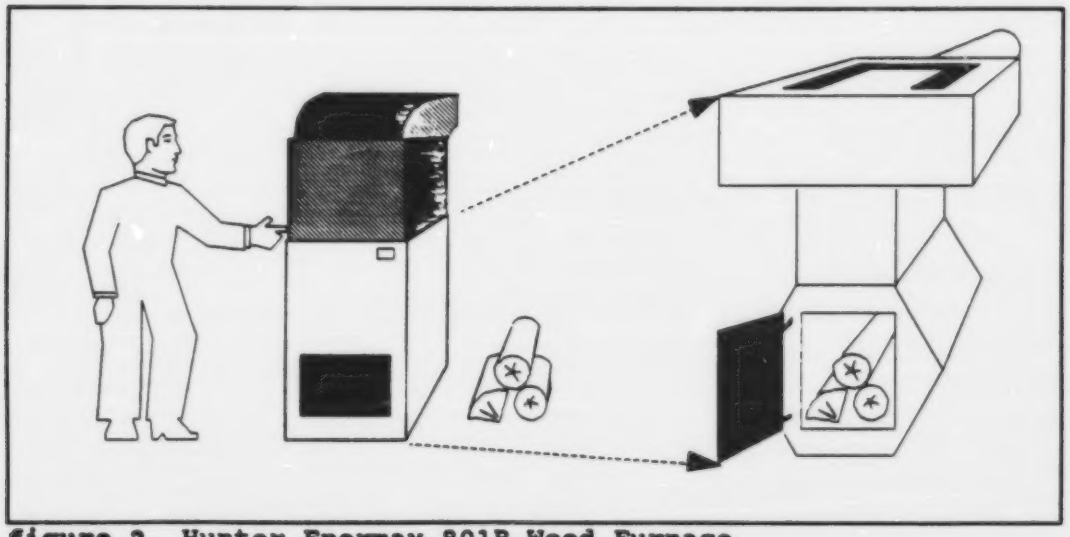

figure 2 Hunter Enermax 801B Wood Furnace

B. Mechanical connection of TP 2000 stoker to Hunter furnace (ref. Photos Appendix C)

It was decided to fit the stoker through the side of the furnace instead of through the loading door. This is the most convenient type of connection because the stoker can remain attached in this position on a semi-permanent basis. Access to the combustor bowl for lighting, inspection and ash removal is provided through the front door.

The sequence in which the TP 2000-30kW stoker was fitted through the side of the Hunter furnace can be seen in photographs 1 to 5. The adapter is also depicted in figure 3.

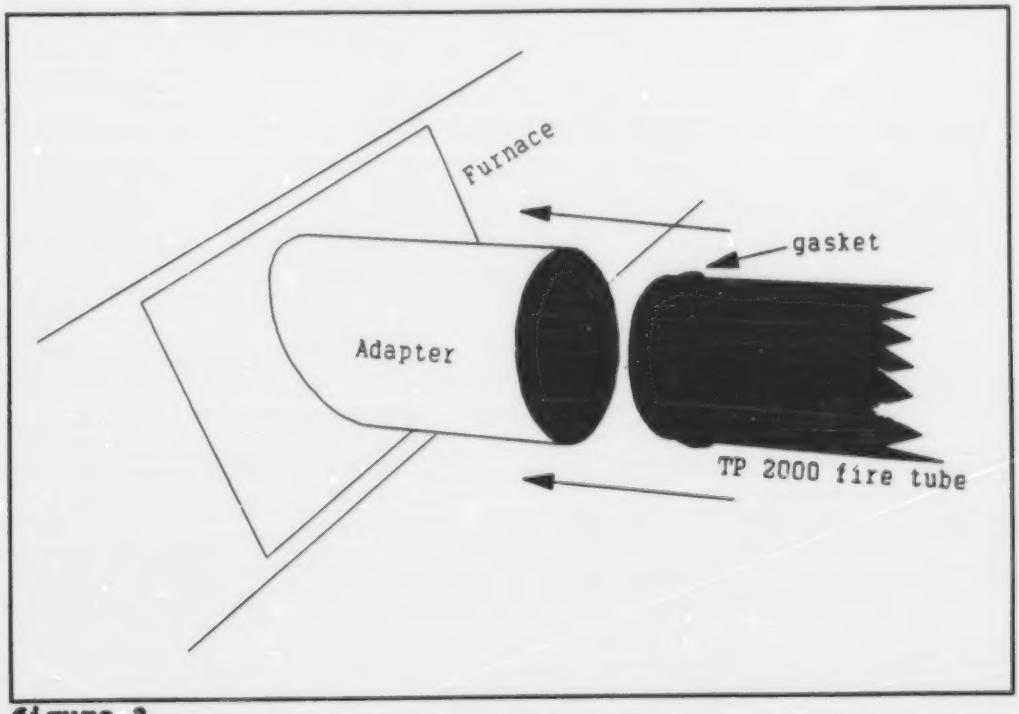

figure 3
Adapter Tunnel for Coupling the TP 2000 to the Hunter Enermax

C. Electrical inter-connection of stoker and furnace

Both the stoker and the furnace had their own separate electrical systems. These were interconnected in order to operate the stoker with the wood furnace as its heat exchanger. Because the furnace would sometimes be operated solely on roundwood, independently of the stoker, electrical systems were interconnected.

The stoker and the furnace were connected to separate thermostats. When the wood furnace was not being operated on roundwood, its thermostat was turned down. The same was done for the stoker's thermostat. The furnace limit switch was interconnected with the stoker controls so that and in the event of overheating of the furnace plenum, it would stop the stoker's operation or, if the furnace was operating on roundwood, it would close the combustion air damper.

D. Modifications to the stoker/furnace installation

Several modifications were made to the installation in order to improve the stoker system's operation, convenience and safety.

1. Access port

From previous experience with this TP 2000 model, we knew that blockages occur fairly frequently where the chips leave the bin to enter the transport tube. Longer chips (pin chips) gradually accumulate in this location. This buildup of chips continues until they block the auger and break its shear pin. To gain access to the chip obstruction without having to empty the bin, an access panel was placed close to this location. An 8-inch diameter hole was cut on the bin side closest to the auger and fitted with a removable cover. This port provided easy access to this problem area.

2. Machining of auger

From previous experience with the TP 2000-30kW stoker we also knew that it was possible to reduce the frequency of blockages in the bin by providing more clearance between the auger and the tube.

The auger was 4 inches in diameter and was set inside a 4-3/4-inch inside diameter tube. To increase the clearance to 5/8 of an inch on each side, we machined the auger to 3-1/2-inch-diameter over all the section which transports chips in the bin.

The auger was subsequently further machined to a diameter of 3 inches with the intent of further reducing the frequency of blockages and lowering the noise level caused from chips trapped between the auger and tube. This attempt was not successful as the smaller-diameter auger floated above chips which accumulated in the bottom of the auger tube. We no longer had our clearances between the auger and tube. The 3-inch auger was replaced with a 3-1/2-inch one.

3. Vibrator

To prevent bridging of fuels in the storage bin, a mechanical vibrator was installed on the bin's exterior surface. The vibrator was wired through a timer, to operate approximately 20 seconds every 10 minutes. The use of a vibrator did not prove to be of much help.

4. Dowser

The TP 2000-30kW is not sold with any protection to prevent burnback of fuel along the tube into the storage bin. Burnback is best stopped by utilising preventive measures. The bin's cover should be well sealed, and remain shut and latched during

operation. We installed two dowser systems on the auger tube. One controlled by a thermostatic valve and the other, in the event that the valve failed to open, was fitted with a wax plug.

The thermostatic valve is a proportional valve: the higher the temperature sensed, the more the valve opens to admit water to the burnback area. When the sensor cools the valve shuts. The wax plug dowser consists of a short piece of 3/4-inch pipe which penetrates the top of the auger tube. This tubing is filled with either paraffin wax or beeswax and is connected to a water pail by plastic tubing. Should the plug melt because of overheating, the pail empties itself into the auger tube. Both these dowsers should extinguish any burnback and wet the fuel sufficiently to prevent any further combustion.

5. Adjustments to hold-fire mode

To maintain its fire, when there is no demand for heat, an adjustable timer provides a cyclic burn period. The cycle can be adjusted between 2 and 6 minutes and the burn time can be adjusted between 5 and 30 seconds. The hold-fire setting consuming the least amount of fuel would be a burn period of 5 seconds every 6 minutes whereas a hold-fire burn period of 30 seconds every 2 minutes would consume the largest amount of fuel. We adjusted the hold-fire timers for this fastest feed, because we wanted to ensure that the fire would not have time to burn back along the tube between feed cycles.

If the stoker remained on hold-fire mode for an entire day, the stoker would go through 720 cycles and operate for 6 hours.

E. Fuels

1. Chips and roundwood

Green hardwood chips were purchased from a sawmill. These chips had a number of long splinters and a high proportion of small material (75% of chips passing through a 12.5 mm sieve - ref. sieve analysis, Appendix B). Both these characteristics were found to be a hindrance as they led to blockages and to the compaction of fuel in the bin. The homeowner had a supply of dry firewood which he could utilize should he encounter problems with the stoker.

2. Storage and handling

We purchased one load or 40 cubic yards of chips and stored them in the grain silo. The chips had a moisture content of approximately 37% w.b., when delivered. A tractor-operated corn blower was used to fill the silo with the chips. The silo provided protection from the rain and easy access to the fuel. While the silo is equipped with a drying blower which forces air through floor perforations, we did not require drying of chips because they never overheated. They kept losing moisture at a rate of approximately 1 to 2% per month during the monitoring period. This had also been the case on previous use of this silo for chip storage.

For transportation to the metering bin the chips were loaded into grain bags.

3. Feed tests

Feed tests were performed on the TP 2000-30kW stoker in order to measure its feed rate at various settings. Knowing the stoker's hours of operation and its rate of feed would allow us to calculate the quantity of fuel used and to calculate the stoker's chip consumption. Feed tests done on both the 4-inch and the smaller 3-1/2-inch diameter auger showed no differences in fuel feed. The auger was set to give a feed rate of 6.5 kg/h (at 1.71 rpm and 35% mcwb[1]). This hourly feed rate was determined for trouble-free operation. We know, from our frequent cleanings, that pin-chip buildup at the auger tube entrance lowers the feed rate.

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[1] A feed rate of 6.5 kg/h at 35% moisture content wet base gives an equivalent of 4.2 kg/h dry rate)

MONITORING PROGRAM

To monitor the operation of the stoker over the heating season, an elapsed time meter and event counter were wired into the stoker's electrical circuit. The elapsed time meter recorded the amount of time the stoker operated. The event counter totalled the number of times the stoker cycled on/off. If the cycling totals were high they would indicate that the stoker had been operating on a hold-fire mode for lengthy periods. On continuous hold-fire the electric motor would cycle 30 times per hour.

The quantity of chip fuel used daily was monitored two ways. First the stoker's feed rate, measured at 6.5 kg/h. (1.71 rpm rotation of auger) was multiplied by the number of hours the stoker operated per day. As a check we recorded the number of bags of chip fuel burnt daily. Chip bags were weighed and were averaged at 18.7 kilograms to estimate the quantity of fuel used.

Meter readings and operating problems were recorded on monitoring forms.

A list of the monitoring data is presented in Tables 1A,1B and 1C.

TABLE 1A - MONITORING DATA FOR T.P.2000-30kW STOKER FOR 1987/88 HEATING SEASON

		1*	2*	3**	4	5	6***	7***	8	
DATE	TIME	ON/OFFS #	ON/OFFS average #/h	HOURS OF OPERATION	% TIME ON hours	# OF BAGS OF CHIPS CONSUMED	WEIGHT OF FUEL CONSUMED HOURS X FEED RATE	WEIGHT OF FUEL CONSUMED BAGS X 18.65 kg	DEGREE-DAYS	COMMENTS
JAN. 7	16:00	131	5.2	19.6	78		127	0	39.2	
JAN. 9	15:30	268	5.6	35.5	75	4	231	75	30.5	
JAN. 10	9:25	142	7.9	12.0	67	5	78	93	32.9	
JAN. 11	8:38	198	8.5	14.7	63	5	96	93	27.0	hex screw falls from auger
JAN. 12	8:36	160	6.7	16.8	70	5	109	93	18.5	
JAN. 13	8:38	206	8.6	15.2	63	5	99	93	29.4	
JAN. 14	9:00	129	5.3	19.0	78	6	124	112	43.1	
JAN. 15	8:48	52	2.2	21.4	90	6	139	112	31.8	
JAN. 16	9:15	68	2.8	21.5	88	4	140	75	19.8	
WEEKLY TOTALS		955		120.6		36	784	671	202.5	
JAN. 17	9:25	327	13.5	10.2	42	4	66	75	15.6	disconnected vibrator (noisy)
JAN. 18	8:47	315	13.5	9.5	41	3	62	56	17.2	
JAN. 19	7:12	512	22.8	11.4	51	2	74	37	19.3	
JAN. 20	9:11	133	5.1	8.1	31	5	53	93	18.3	
JAN. 21	16:23	339	10.9	16.2	52	3	105	56	23.1	
JAN. 22	8:45	116	7.1	11.2	68	5	73	93	31.1	
JAN. 23	10:00	266	10.5	13.3	53	4	86	75	27.5	
WEEKLY TOTALS		2008		79.9		26	519	485	152.1	
JAN. 24	9:45	220	9.3	14.2	60	4	92	75	19.3	cleaned chips from auger
JAN. 25	18:50	367	11.1	16.5	50	3	107	56	24.7	
JAN. 26	8:28	132	9.7	7.7	56	5.5	50	103	33.0	
JAN. 27	7:56	151	6.4	16.8	72	5	109	93	36.0	
JAN. 28	7:54	69	2.9	20.8	87	4	135	75	31.7	
JAN. 29	16:51	202	6.1	23.7	72	4	154	75	28.8	
JAN. 30	9:27	62	3.7	13.9	84	3	90	56	17.1	cleaned chips from auger
WEEKLY TOTALS		1203		113.6		28.5	738	532	190.6	
MONTHLY TOTALS		4565		369.2		95	2400	1762	615	

* The maximum number of on/off cycles per day is 720 (30/h). This would be obtained if the stoker was on continuous hold-fire mode.

** The maximum hours of operation would be 24 per 24-hour period. The minimum would be 6 if the stoker was on hold-fire all day.

*** Wet weight of fuel at 35% mcwb.

TABLE 18 - MONITORING DATA FOR T.P.2000-30kW STOKER FOR 1987/88 HEATING SEASON

		1*	2*	3**	4	5	6***	7***	8	
DATE	TIME	ON/OFFS #	ON/OFFS average #/h	HOURS OF OPERATION	% TIME ON hours	# OF BAGS OF CHIPS CONSUMED	WEIGHT OF FUEL CONSUMED HOURS X FEED RATE	WEIGHT OF FUEL CONSUMED BAGS X 18.65 kg	DEGREE-DAYS	COMMENTS
JAN. 31	17:08	425	13.4	12.8	40	3	83	56	18.6	
FEB. 1	14:34	321	15.0	7.1	33	4	46	75	17.1	
FEB. 2	8:58	500	27.2	20.1	100	5	131	93	29.1	
FEB. 3	8:17	198	8.5	14.5	62	2	94	37	35.4	
FEB. 4	8:28	202	8.4	15.2	63	4	99	75	31.8	
FEB. 5	8:37	109	4.5	19.4	80	2	126	37	36.4	
FEB. 6	7:39	36	1.6	19.4	84	6	126	112	35.3	
WEEKLY TOTALS		1791		108.5		26	705	485	203.7	
FEB. 7	9:02	38	1.5	25.7	100	3	167	56	33.7	cleaned chips from auger
FEB. 8	8:29	138	5.9	17.1	73	4	111	75	30.3	
FEB. 9	8:19	161	6.8	16.7	70	5	109	93	33.3	
FEB. 10	7:35	157	6.8	16.4	70	4	107	75	30.7	cleaned chips from auger
FEB. 11	8:12	121	4.9	19.1	78	6	124	112	32.6	
FEB. 12	10:00	74	2.9	11.7	45	5	76	93	26.2	
FEB. 13	16:56	78	2.8	11.3	40	3	73	56	28.3	
WEEKLY TOTALS		767		118.0		30	767	560	215.1	
FEB. 14	9:07	77	4.0	15.8	82	3	103	56	28.1	
FEB. 15	8:53	196	8.3	14.5	61	6	94	112	19.3	cleaned chips from auger
FEB. 16	18:05	330	9.9	18.4	55	5	120	93	26.2	
FEB. 17	9:01	92	6.2	10.8	72	5	70	93	22.1	
FEB. 18	18:00	401	12.2	14.9	45	3	97	56	21.1	
FEB. 19	8:28	106	7.3	10.3	71	3	67	56	18.2	
FEB. 20	14:00	337	11.4	14.3	48	4	93	75	24.1	cleaned chips from auger
WEEKLY TOTALS		1539		99.0		29	644	541	159.1	
FEB. 21	8:11	101	5.6	13.3	73	5	86	93	35.3	
FEB. 22	9:44	44	1.7	23.5	92	7	153	131	21.4	
FEB. 23	6:44	0	4.8	21.0	100	3	137	56	20.5	
FEB. 24	7:40	459	14.4	16.3	65	2	106	37	25.8	
FEB. 25	8:19	45	1.8	10.7	43	4	70	75	27.0	cleaned chips from auger
FEB. 26	8:10	268	11.2	11.7	49	3	76	56	27.3	cleaned chips from auger
FEB. 27	13:00	335	11.6	13.7	48	3	89	56	24.8	
WEEKLY TOTALS		1252		110.2		27	716	504	182.1	
MONTHLY TOTALS		5385		455.1		118	2958	2201	795	

TABLE 1C - MONITORING DATA FOR T.P.2000-30kW STOKER FOR 1987/88 HEATING SEASON

		1*	2*	3**	4	5	6***	7***	8	
DATE	TIME	ON/OFFS #	ON/OFFS average #/h	HOURS OF OPERATION	% TIME ON hours	# OF BAGS OF CHIPS CONSUMED	WEIGHT OF FUEL CONSUMED HOURS X FEED RATE	WEIGHT OF FUEL CONSUMED BAGS X 18.65 kg	DEGREE-DAYS	COMMENTS
FEB. 28	10:27	245	11.4	10.7	50	4	70	75	24.6	
FEB. 29	8:10	235	10.8	11.2	52	5	73	93	25.9	
MAR. 1	8:18	200	8.3	15.3	63	5	99	93	34.0	
MAR. 2	8:40	158	6.5	17.3	71	6	112	112	30.8	
MAR. 3	8:13	97	4.1	19.3	82	4	125	75	26.3	
MAR. 4	17:00	405	12.4	14.4	44	4	94	75	27.9	
MAR. 5	16:30	211	9.0	14.3	61	4	93	75	26.3	
WEEKLY TOTALS		1551		102.5		32	666	597	195.8	
MAR. 6	16:45	222	9.2	14.3	59	3	93	56	19.6	
MAR. 7	8:30	127	8.1	10.2	65	4	66	75	18.7	
MAR. 8	18:30	500	14.7	11.6	34	3	75	56	22.9	
MAR. 9	10:50	76	4.7	13.0	80	3	85	56	17.5	
MAR. 10	10:00	303	13.1	9.1	39	0	59	0	19.7	
MAR. 11	9:35	254	10.8	15.4	65	4	100	75	25.7	cleaned chips from auger
MAR. 12	9:45	167	6.9	16.4	68	4	107	75	26.6	
WEEKLY TOTALS		1649		90.0		21	585	392	150.7	
MAR. 13	9:35	50	2.1	9.7	41	6	63	112	22.5	
MAR. 14	8:23	127	5.6	17.1	75	3	111	56	20.9	
MAR. 15	17:15	261	7.9	13.9	42	2	90	37	19.7	power outage
MAR. 16	17:25	336	13.9	9.1	38	2	59	37	18.3	
MAR. 17	17:19	331	13.9	9.1	38	3	59	56	20.6	
MAR. 18	17:34	225	9.3	14.2	59	4	92	75	20.4	
MAR. 19	17:15	236	10.0	13.2	56	2	86	37	23.9	
WEEKLY TOTALS		1566		86.3		22	561	410	146.3	
MAR. 20	8:53	74	4.7	12.3	79	5	80	93	29.5	
MAR. 21	17:49	265	8.1	21.2	64	5	138	93	32.3	
MAR. 22	17:00	175	7.6	15.3	66	3	99	56	27.6	
MAR. 23	9:13	98	6.0	11.9	73	4	77	75	19.0	
MAR. 24	23:00	575	15.2	12.1	32	1	79	19	14.2	
MAR. 25	19:00	258	12.9	8.4	42	3	55	56	13.4	
MAR. 26	16:12	304	14.3	7.6	36	1	49	19	8.7	
WEEKLY TOTALS		1749		88.8		22	577	410	144.7	
MONTHLY TOTALS		6726		381.9		101	2482	1884	664	

ANALYSIS OF MONITORING DATA

Analysis of the monitoring data of TABLES 1A, 1B and 1C reveal:

1. The two methods used to measure the quantity of fuel consumed differ by 25%. Total fuel consumed (at 35% mcwb) as measured by the auger operating time is of 7441 kg whereas the measurement according to bag count is of 5959 kg. The quantities obtained from the auger operating time are higher than the quantities obtained from a measure of the fuel bags used. It is understandable that the auger does not always feed at its maximum rate of 6.5 kg/h (at 1.71 rpm) because of clogging at the auger tube entrance. This would account for the actual lower total obtained from the bag count.

2. From a previous study of this house[2] we had determined the energy need to be of 83,220 MJ over a 12 month period from mid February, 1985 to mid February, 1986. This period had a total of 4337 degree-days C (below 18°C).

Knowing that there have been 2098 degree-days for this monitoring period, from January 7 to April 2, 1988 we can infer the energy need for the house over this period has been of

$$\frac{\text{2098 degree days}}{\text{4337 degree days}} \times 83220 \text{ MJ} = 40257 \text{ MJ}.$$

The heating system consumed 4355 dry kg of fuel over this period. At 18.90 MJ/kg, this means a gross calorific value of

$$4355 \text{ kg} \times 18.90 \text{ MJ/kg} = 82{,}310 \text{ MJ}$$

This would place the system seasonal efficiency at

$$100 \times \frac{40257 \text{ MJ}}{82310 \text{ MJ}} = 48.9\%$$

This is very similar to the operating efficiency found on the Eshland Wood Gun E100, during the previous study.

---

[2]Monitoring and Testing of the Eshland Wood Gun Model E100 Wood Fired Boiler, Charles LeMay, I.R.T.A., July 1986.

3. The stoker operated on average 21 hours daily during the month of January, 16 hours during February and 15 hours for March. We notice that the daily hours of operation are all above 6 hours, the minimum amount of time the stoker operates daily on continuous hold-fire mode.

On continuous hold-fire over an entire day, the stoker would operate for 6 h and consume 6 h x 6.5 kg/h = 39 kg of chips. This is equivalent to 2 bags of fuel per day, whether the heat is required or not.

If the stoker was operated at a much lower hold-fire setting or was fitted with automatic ignition there would be substantial savings in the amount of fuel consumed. We would estimate that this would amount to between 50 and 100 bags of fuel per year if the same hold-fire settings were used. This cutback represents up to 16% reduction in fuel consumption.

A lower setting on hold-fire operation or an automatic ignition would show substantial effect on the system's seasonal fuel consumption. There would be less excess heat generated on calm sunny days or in early fall and spring. This would amount to an effective increase in system efficiency. The efficiency would then climb from 49% to 59%, closer to the optimum lab results of 68%[3]. With finer adjustment to the whole system, this 68% could probably be matched.

4. The stoker cycles through hundreds of on/off cycles daily. We question whether the motors and switches were designed for this type of operation.

5. From other research work[3] done on particulate fuel burners at IRTA labs we have summarized some of the TP 2000-30kW test results.

- the stoker had very low particulate emission levels, less than 5 g/h when operated with chips at 35% mcwb.
- the Hunter Enermax 801B wood furnace was shown to be an efficient heat exchanger when used with the TP 2000-30kW stoker. The system yielded an average efficiency of 68% according to B415 calculations.
- The TP 2000-30kW was able to attain an average maximum burn rate of 9 kg/h of hardwood chips for an output of 102 MJ/h (97,000 Btu/h or 28 kW) @ 60% efficiency.

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[3]Establishment of Criteria for the Retrofit of Chip Stokers to Furnace/Boilers to Burn Roundwood, a report to E.M.R. by IRTA, October 1988.

6. Payback analysis

PAYBACK ANALYSIS

		Actual 49% efficiency		Projected 59% effic.		Projected 69% effic.	
		1x	2x	1x	2x	1x	2x
YEARLY							
Cost of fuel	$	599	1199	498	996	426	851
Maintenance	$	125	125	125	125	125	125
Total cost	$	724	1324	623	1121	551	976
Fuel oil savings[4]	$	1220	2440	1220	2440	1220	2440
Cost difference	$	496	1116	597	1319	669	1464
Amortization:							
potential	$	6425	6460	6176	6396	6325	7095
period (years)		14	6	11	5	10	5

Notes:

1) Amortization is calculated on the basis of 12.5% per annum.

2) Total cost of installed system, including the purchase of the TP 2000-30 kW stoker and a heat exchanger (hot air furnace): $6,400.

3) 1x means the actual yearly demand of 83,220 MJ.
2x means a demand twice as high (166,440 MJ).

4) From the above table, at the present price of oil, if the appliance was adjusted for an efficiency of 69%, it would be repaid in 10 years.

If the appliance was used at twice the actual output, it could be repaid in less than 5 years.

---

[4]Based on $0.329/l

OBSERVATIONS ON STOKER'S OPERATION

A. Maintenance requirements

1. Ash removal

There was no problem with the removal of ash from the heat exchanger because of the easy access through the heat exchanger's front loading door. The stoker required regular ash removal and this task was done approximately every three weeks. Usually, the small clinker formation in the combustion tube would be pushed off the edge by incoming chips. Occasionally, there was some clinker buildup in the combustion tube and when it did not fall, it had to be removed manually.

2. Removing chips that jammed auger

The stoker required regular cleaning of chips that jammed around the auger at the entrance to the auger tube at the base of the bin. An accumulation of long splintered chips at this location, if not removed, would eventually obstruct the auger and break the shear pin. This cleaning of chips from the auger was done once and sometimes twice weekly by gaining access to this area through the access port. Cleaning was usually done when the chip level in the bin was low. It required approximately 10 to 15 minutes.

3. Operation of dowsers

There were no major problems with the operation of the dowsers once they were adjusted. One night, before adjustment, the dowser's thermostatic valve opened and extinguished the fire. The sensor had been positioned too close to the combustor bowl, overheated, and opened the thermostatic valve. Since this system does not have a photoelectric flame detector, the stoker continued to operate and feed chips into the bin as if the stoker was still lit. The more the thermostat called for heat, the more the heat exchanger was being filled with unburned chips. The next morning the mess was observed by the homeowners. The furnace was then emptied of chips and the heat sensor was re-positioned a bit further from the combustor tube.

On several occasions we noticed that the water pail supplying the dowser system with the wax plug was empty. The water was evaporating in the pail. This indicated the need for a covered container.

4. Time requirements

The homeowner estimated at about 15 minutes a day the time required for filling the bin with chips. About 20 minutes a week were taken up by the removal of ash from the furnace and of splinter chips from the bin.

B. Problems with stoker

1. No detection of loss of fire

The TP 2000-30kW stoker was not equipped with a means of detecting loss of flame in the appliance. In this eventuality, the stoker would continue feeding chips into the firebox and it would fill the furnace with chips until the appliances were pushed apart. This would usually require the cleanup of large quantity of chips.

There are several types of devices which are commonly used to prevent fuel flow should the fire become extinguished. Photocells are used to detect loss of fire. They are wired into the electrical circuit and stop the supply of fuel to the combustion chamber. Overfill or high level switches are also used to prevent overflow of material. Either of these devices, if they could be adapted to the TP 2000's design, would solve its problem of detecting loss of flame.

2. Better burnback prevention

The TP 2000-30kW stoker requires design changes to prevent burnback instead of providing protection to stop the burnbacks once they are initiated. Feed breaks, safety latches on the bin covers and good sealing against air leakage are commonly used for burnback prevention and could be used here.

The homeowners expressed concern about fire backing up along the feed tube and reaching the bin. IRTA was also concerned with this eventuality. For this reason, the hold-fire mode was adjusted to its maximum feed rate, to prevent the fire from burning back along the tube during the off cycles. This situation would be of concern during period of extended hold-fire. This solution seems to be quite effective but with a minimum consumption of 2 bags of fuel daily, it is an expensive solution to the burnback problem.

3. Operating noises

After three weeks of operation, the mechanical vibrator was disconnected because it was too noisy, even for use during the day. From another study it was found that vibrators provided minimum protection against fuel bridging. The vibrators also compacted fuel in the bin, which led to a variety of feed problems.

When the stoker was first operated, it produced a variety of screeching noises as larger chips were squeezed against the auger tube. After the auger was machined to a smaller diameter the noise diminished. When this was mentioned at the chip combustion

workshop[5], we were told that a common practice in Scandinavian countries is to add small amounts of old oil on top of a full bin of chips: this has the effect of lubricating the auger while recycling fuel.

4. Need for operating instructions

There were no operating instructions supplied with the appliance. Because we were fairly familiar with the stoker's operation, we were able to get by without it. An instruction manual would be necessary for first time operators.

5. Other comments

a) We broke several shear pins on the TP 2000-30kW stoker and could not find any replacements of the proper size. We had to use 6-inch standard nails as shear pins.

b) A hex screw connecting the ox-yoke mechanism to the electrical motor shaft would loosen, with the result that it would no longer turn the auger ratchet. It required regular re-tightening.

C. Homeowner satisfaction

The homeowners were highly satisfied with the operation of the stoker system. They welcomed the saving in time associated with chip burning as opposed to roundwood. While the handling of chips is still time consuming, it proved to be considerably less work than heating with roundwood. The homeowners will utilize this heating system for another year.

---

[5]Chip Combustion Workshop, sponsored by E.M.R. and held in Rockland, Ontario, in June, 1988.

CONCLUSIONS

1. The TP 2000-30kW stoker connected through the side of the Hunter 801B furnace operated very well over the 1987/88 heating season when fuelled with sawmill chips. The stoker provided the major share of the Glaude's residence heating and was able to maintain comfort level throughout the heating season.

2. The TP 2000-30kW stoker would be improved if its design incorporated loss of flame detection, burnback protection, and an instruction manual.

3. When the TP 2000-30kW stoker is operating on a high hold-fire setting for extended periods of time (early fall, spring), it supplies unnecessary heat to the house. This waste heat production could be either minimized by lowering the hold-fire setting or even eliminated by incorporating an automatic ignition system.

4. The TP 2000-30kW is capable of a maximum output in the range of 100 MJ/h (approximately 30 kW or 100,000 Btu/h). This implies that it could easily heat more than twice the Glaude house (a 1500 sq. ft. bungalow, poorly insulated). It could handle commercial installations such as a small woodworking shop or a 100 foot greenhouse.

Appendix A

Advertising brochures:
TP 2000 and Hunter Enermax

Tehokasta tekniikkaa pannuhuoneeseen

TP 2000 poltin

- Laita TP 2000 poltin kattilaasi — kotimaisen polttoaineen helpoin käyttötapa.
- Ei savuhaittoja.
- Polttoaineena hienohake, palaturvemurske tai pelletti.
- Poltin on automaattinen ja varmatoiminen.
- Erittäin korkea hyötysuhde takaa vähäisen polttoaineen kulutuksen.

Kolme kokoa:
- 180/10 kW
- 360/17 kW
- 500/25 kW

- Poltin voidaan asentaa useimpiin eri kattilatyyppeihin.

MYYJÄ:

Timi
Topi Pämppi
27100 EURAJOKI
☎ 938-80 222

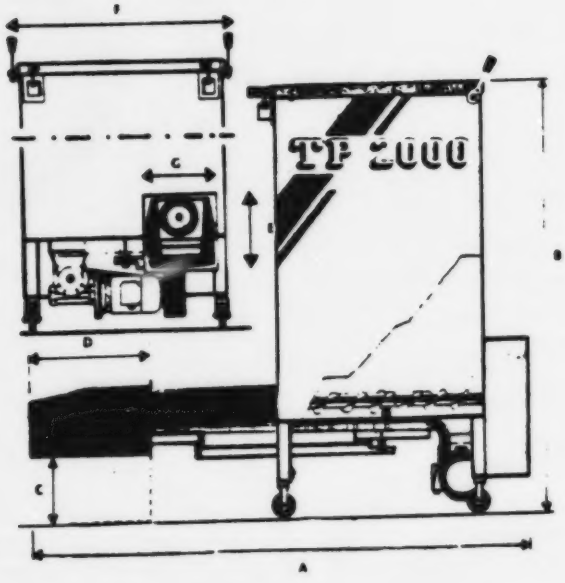
TP 2000 STOKER

FOR
BIOFUEL COMBUSTION

FOR WOODCHIPS AND VARIOUS FUEL PELLETS.
Capacities: 30 000, 60 000, 90 000 & 150 000 BTU

TP 2000 STOKER

Measurements
(in inches)



	Capacities x 1000 BTU			
	30	60	90	150
A	43	57	61	79
B Min	45	51	51	59
B Max	49	51	51	--
C Min	13	12	12	20
C Max	17	13	13	20
D	12	14	15	16
E	Ø5	Ø7	10	12
G	Ø5	Ø7	10	12
F	20	24	28	40
Volume of reservoir (gal)	47 g	94 g	130 g	260 g
Weight lbs	240	280	400	660

The function of the stoker is regulated by the control panel which is connected to the boiler thermostat of a hot-water boiler or a room thermostat in a hot-air furnace system. The stoker burner operates only when heat is required. The fuel is kept smoldering by the control unit when heat is not required.

The combustion bowl is cast iron. A fixed grate is used in the two smallest units, otherwise a mechanical grate is employed.

The noise level of a stoker is low and therefore not disturbing. Due to the good stoker unit design, fuel can be added into the reservoir during its operation without any smoke escaping.

Recommended fuels:

- -woodchips
- -various fuel pellets.

Moisture content of the fuel should be 10% - 30%.

HUNTER

Enermax®

The Ultimate Wood Burning Furnace System!

In the Enermax line Hunter has created a furnace for those who are serious about heating their homes with wood.

The challenge was to build a unique furnace which would combine safety and efficiency with trouble-free performance and reliability. The Enermax is the result, a furnace that delivers heat as promised and saves money as a result of more efficient combustion.

An Enermax wood furnace alone—or when combined with gas, oil or electricity for back-up—results in burning less wood for more heat with many years of trouble-free performance.

Enermax—The Ultimate Furnace System for the thoughtful homeowner.

Hunter Enermax The Ultimate Furnace System

Hunter customers expect the best. Since 1937 Hunter has not disappointed North American homeowners in providing heating equipment which is efficient, durable, reliable and includes the type of quality features that are synonymous with Hunter products.

Owners of Hunter gas, oil, electric, wood or combination fuel heating equipment are prepared to spend a little bit more to get trouble-free equipment that lasts a little longer than those other makes.

Presenting the Enermax line, Hunter incorporates a method of burning wood that is unique to the industry providing a furnace to those who are still serious about burning wood for whatever reason that it makes sense. Whatever the price of those other fuels, burning wood with an Enermax means you will burn less wood and save more money and have many years of trouble-free heating.

Enermax The Unique Features For You

Depending on the model the Enermax series can meet a wide range of heat needs depending on the size of the house. For small houses, 65,000 to 98,000 BTU range furnaces; larger houses 100,000 to 160,000 BTU range. For safety it is mandatory to match the heat needs of the house with the equipment.

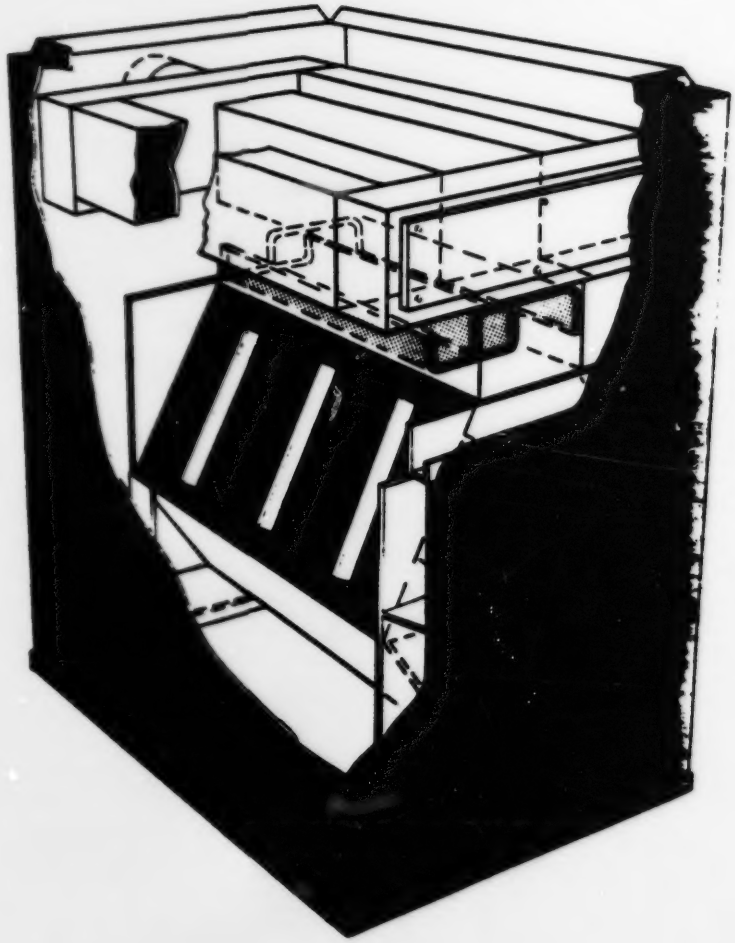
Maintenance ease—Enermax makes life simpler and safer with large front access clean-out ports closed with easy-to-adjust brass nuts.

Efficiency—The unique three-tube Hunter secondary heat exchanger means that with the exclusive combustion tunnel less heat escapes up the chimney—more heat goes into the home and 25% less wood is used. Many other furnaces do not even have secondary heat exchangers.

Increased Heat—Enermax's exclusive refractory combustion tunnel means added gas ignition producing more heat—only Enermax has this in the 801 series.

Safety—Enermax has incorporated 12 ga. steel in the heat exchanger and 8 ga. steel in the combustion chamber to give maximum reliability and long life. Hunter guarantees both the combustion chamber and the heat exchanger for five years unlike other makes.

Quality Features—It's the little things, the door handles, the best electrical controls, the superior welding, the baked enamel paint finish—these are the ingredients of quality which means trouble-free operation for the home-owner.



THE IDEAL CHOICE

For long-term customer satisfaction it is essential every home-owner discusses his heating needs with a professional mechanical contractor to choose the right size furnace for his home with the right combination of fuels for maximum saving and trouble-free warm winters.

Independent wood furnace—for home-owners who want a wood furnace with its own blower because they already have electric heat in baseboards or they just want a plain wood furnace with its own blower the Enermax answer is the 801B for homes needing 65,000 to 95,000 BTU's and the 101B for homes requiring 100,000 to 160,000 BTU's.

- Ideal for even balanced thermostatically controlled wood heat for small homes as a primary heating system or those with baseboard electric heating.
- Can be used in conjunction with existing masonry or approved factory built chimney.
- A complete furnace with all electric controls.

WOOD/ELECTRIC

801CE & 101CE. Thousands of new home-owners and builders across Canada already have recognized the value and utility of Hunter's Wood/Electric. The new Enermax wood/electric eliminates unnecessary pre-heating of the firebox of the wood furnace when in the electric mode providing direct heat into the home.

The combination wood/electric is the most efficient fuel combination given reasonable cost for wood. The basic theory—a wood furnace with a back-up of an electric furnace with the capability for automatic switching from wood to electric when the home-owner is away for a continuous period.

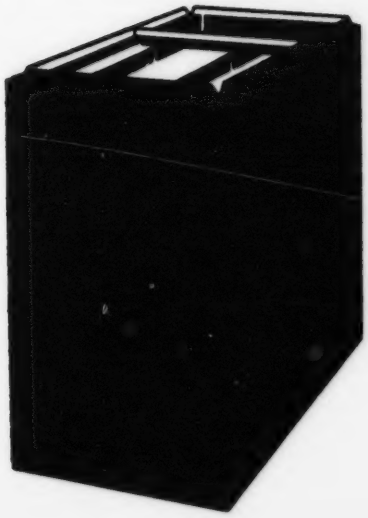
There are two sizes: the 801CE for homes needing 65,000 to 95,000 BTU's and 15 KW electric heat; and the 101CE for homes demanding 100,000 to 160,000 BTU's and 20 KW electric.

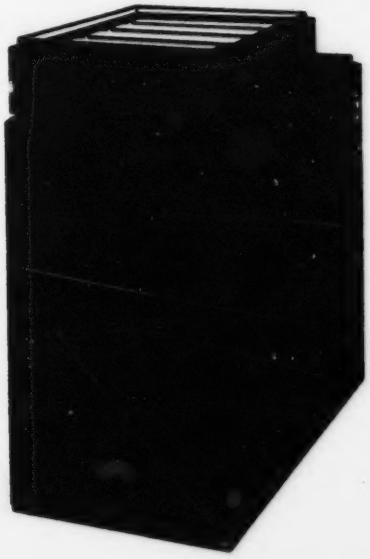
- Automatic switching from wood to electric.
- Clean-safe alternate fuel.
- Extremely compact.
- Optimum heat transfer with coil type elements.

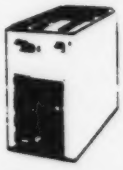
Wood add-on to Oil or Gas. (801A & 201A). The most efficient combination of fuels can be wood and oil or wood and gas for maximum dollars savings. A wood furnace added on to an existing oil or gas furnace is more efficient, easier to maintain, easier to install and one third less expensive than a combination single unit. Depending upon the size of the home it comes in two sizes: the 801A for homes needing 65,000 to 95,000 BTU's and the 201A for homes needing 100,000 to 160,000 BTU's.

- The economical way to provide a wood/oil or wood/gas* combination furnace.
- Designed as a primary or back-up wood-burning furnace to work in conjunction with existing oil or gas furnace forced air system.*
- Fully equipped with all electric controls: damper motor, fan high limit control, thermostat and switching relay.
- Uses existing ducting and fan of existing furnace.
- Can be used in conjunction with existing masonry or approved factory built chimney.

* As applicable according to local codes.





MODEL NO.	ADD-ON & OIL/GAS 801A	INDEPENDENT WOOD 801B	WOOD/ ELECTRIC 801CE	ADD-ON TO OIL/GAS 201A	INDEPENDENT WOOD 101B	WOOD/ ELECTRIC 101CE
						
BTU Range Wood Electric	65,000–98,000	65,000–98,000	65,000–98,000 15 KW 49,200	100,000–160,000	100,000–160,000	100,000–160,000 20 KW 66,000
Height	45"	45"	54"	45"	45"	54"
Width	26¼"	26¼"	26¼"	26¼"	26¼"	26¼"
Length	31¼"	42⅛"	42⅛"	40¾"	53"	53"
Flue	7"	7"	7"	8"	8"	8"
Shipping Weight	395 lbs.	460 lbs.	510 lbs.	490 lbs.	590 lbs.	640 lbs.
Firedoor Opening	12 x 14	12 x 14	12 x 14	12 x 14	12 x 14	12 x 14
Hot Air Plenum	24⅛ x 29⅛	24⅛ x 25⅛	24⅛ x 25⅛	24⅛ x 39	24⅛ x 31⅛	24/⅛ x 31⅛
Cold Air Return	12 x 20	24⅛ x 13⅛	24⅛ x 13⅛	12 x 20	18¼ x 24⅛	18¼ x 24⅛
Blower	N/A	⅛ HP, 9" Sgle	⅛ HP, 9" Sgle	N/A	⅛ HP, 10" Sgle	⅛ HP, 10" 2 spd
Warranty on Firebox and Heat Exchanger	5 yr.	5 yr.	5 yr.	5 yr.	5 yr.	5 yr.
Oil Furnace Sizing	0.75 to 1.25	—	—	0.85 to 1.25	—	—
Firebox Height	20"	20"	20"	20"	20"	20"
Width	20⅛"	20⅛"	20⅛"	20"	20"	20"
Length	19¾"	19¾"	19¾"	28⅛"	28⅛"	28⅛"
Construction Frbox	8 GA	8 GA	8 GA	8 GA	8 GA	8 GA
Heat Exchanger	12 GA	12 GA	12 GA	12 GA	12 GA	12 GA
Elements Type	—	—	Coil	—	—	Coil
Warranty	—	—	1 yr.	—	—	1 yr.

Hunter's growth is a result of meeting the increasing demand for gas, oil, electric and wood heating equipment produced by Hunter's Home Products Division. All of these products are first tested in Hunter's own laboratory before testing or approval by Canadian or U.S. testing and approval laboratories.

You can depend on Hunter quality—it's guaranteed.

Hunter

P.O. Box 400, Orillia, Ontario L3V 6K1 telephone 705/325-6111

APPROVED WOOD ADD-ON FURNACE AND ELECTRIC FURNACE LISTED BY CSA

81 Printed in Canada

Appendix B

Sieve Analysis of Chip Fuel

FONDEX LTÉE
HULL MONT-LAURI

GRANULOMÉTRIE

CLIENT: IRTA - Clarence Creek

PROJET:

PROVENANCE DU MATÉRIAU: Claude Brunet

DATE ÉCHANTILLONNÉ: 12 Janvier 1988 PAR: Client

DATE LIVRE: 12 Janvier 1988 PAR: Client

NO. DU LABORATOIRE: 1524 DATE D'ESSAI: 15 Janv.

MATÉRIAU EMPLOYÉ: Copeaux de bois

DEVIS:

POIDS DE L'ÉCHANTILLON:

TAMIS NO.	PDS. RETENU	% RETENU	% RETENU CUMULATIF	% PASSANT	LIMITES DU DEVIS-% PASSA
37.5 mm				100	
25				97.9	
22.4				95.5	
19				91.1	
16				81.9	
12.5				74.0	
9.5				37.3	
4.75				5.5	

MODULES DE FINESSE:

REMARQUES:

ESSAI PAR: T.M. DATE: 15 Jan. 1988

VÉRIFIÉ PAR: SB DATE: 15 Jan. 1988

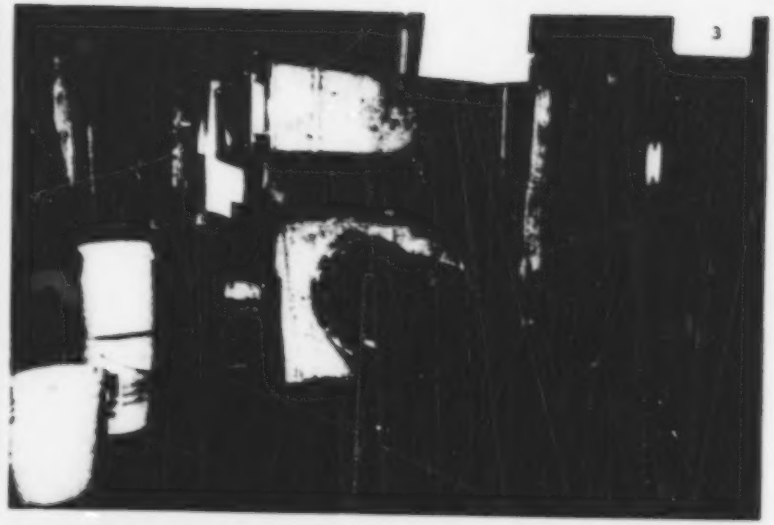
COPIES:

Appendix C

List of photographs

1. Hole cut in wall of Hunter furnace with torch.
2. Hole edges being ground prior to fitting of tunnel.
3. Adapter plate and tunnel welded to furnace.
4. Hunter furnace and TP2000 ready for coupling.
5. TP2000 coupled to Hunter furnace.
6. Two-douser systems installed on the feed tube. Notice access port on lower left of bin and vibrator mounted on bin wall.
7. Ratchet and ox-yoke attachment.
8. Stoker's cast steel combustor tube.
9. Vibrator fixed to bin wall.
10. Timing to determine rotational speed (RPM) of auger.
11. Measuring along ox-yoke assembly to set auger speed.

1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2

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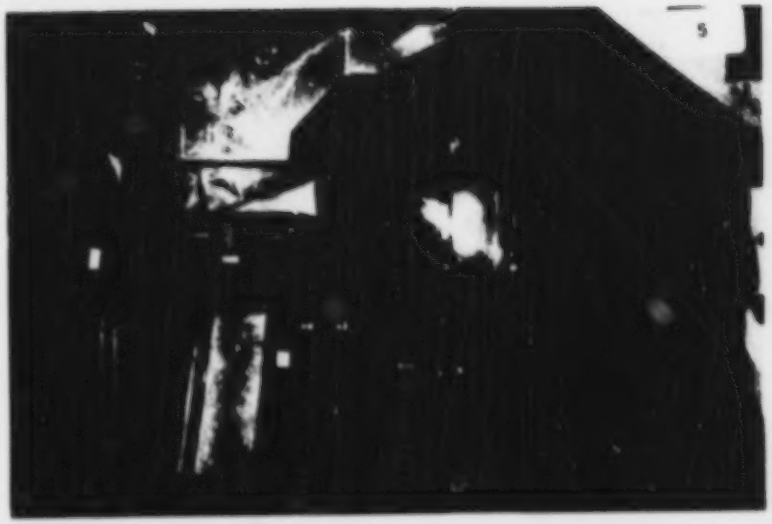
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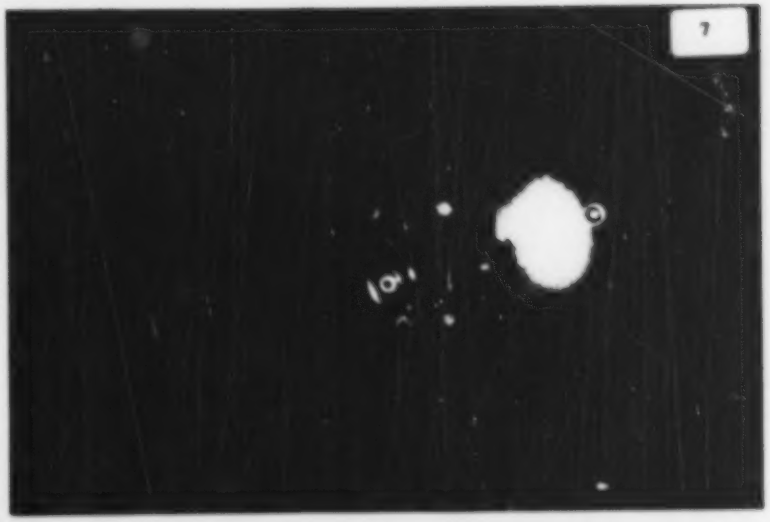
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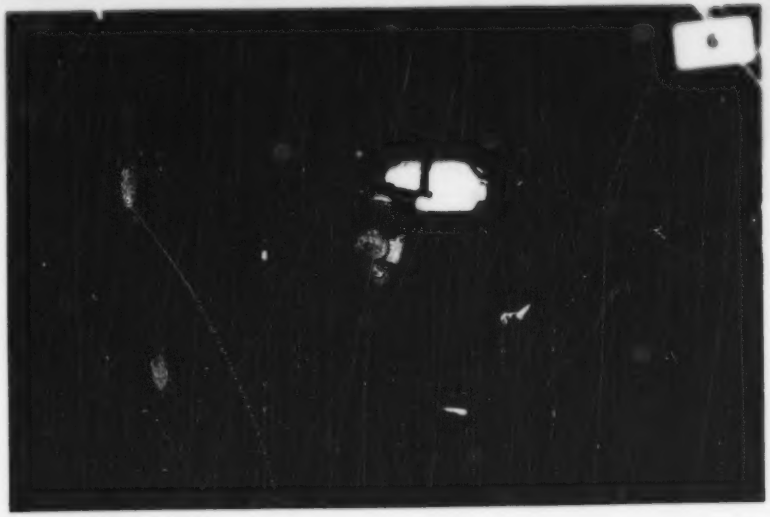
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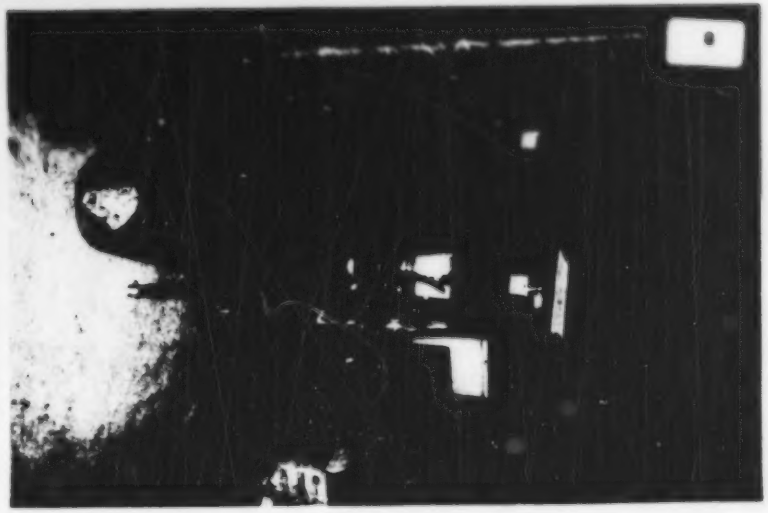
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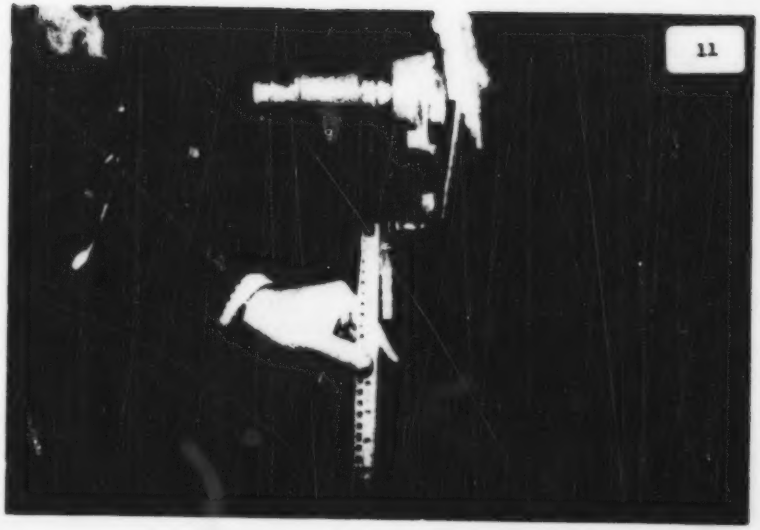
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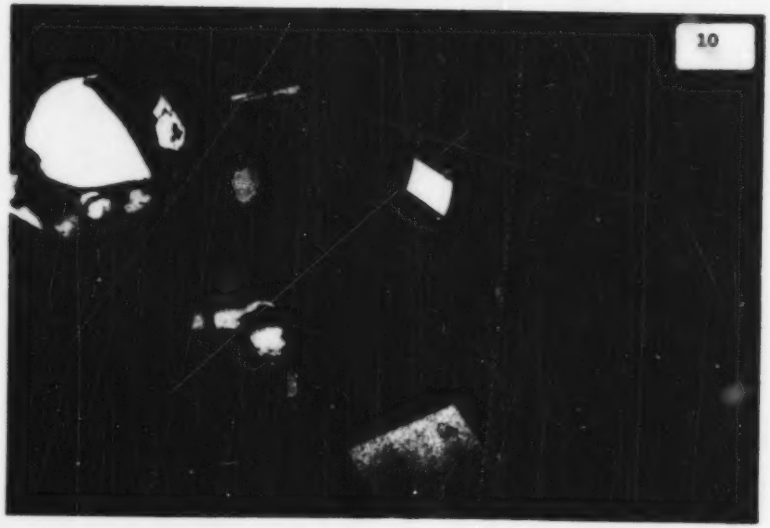
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